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Estimating plate-based model food proportions in adults living in Scotland using short dietary assessment questionnaires.

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ABSTRACT

Aim: To determine whether an FFQ and a short dietary assessment tool can be used to accurately estimate the Eatwell Guide proportions (a plate-based food model) of diets of adults living in Scotland.

Methods: The cross-sectional study was conducted as a follow-up of the 2010 Scottish Health Survey (participants aged 18-65 years old). Proportions of the Eatwell Guide food groups (starchy carbohydrates, fruits and vegetables, dairy and alternatives, protein foods, and oils and spreads) were calculated from the Scottish Health Survey Eating Habits Module (SHeS EHM), Scottish Collaborative Group Food Frequency Questionnaire (SCG FFQ) and a seven-day estimated food diary (reference method), and compared using the Aitchison method and Wilcoxon Signed-Rank Test. Bland-Altman analyses assessed mean difference and 95% limits of agreement between the methods for each food group.

Results: Ninety-six adults were included (mean (SD) age=51.4(11.1) years, BMI=27.1(4.9) kg/m²; 58% female). The SCG FFQ scored a lower median Aitchison distance (1.47) than the

SHeS EHM (1.99) ($p < 0.001$), showing greater agreement with the reference method ($P < 0.001$).

Bland Altman plots also showed better agreement for the SCG FFQ than the SHeS EHM.

Poorest agreement was for starchy carbohydrates (both methods), protein foods (SHeS EHM) and dairy (SCG FFQ).

Conclusions: The SCG FFQ could be used to estimate Eatwell Guide proportions and monitor compliance to the Eatwell Guide recommendations, and could be improved with small changes.

The SHeS EHM is less suitable, but additional questions on dairy foods, and oils and spreads would improve its ability to estimate the Eatwell Guide proportions.

Key words: surveys and questionnaires, nutrition policy, health promotion, public health, diet

INTRODUCTION

Many countries have national dietary models to guide people to make healthier dietary choices such as the United States Department of Agriculture Human Nutrition Information Service ‘MyPlate’¹, the Australian Guide to Healthy Eating², and China’s Food Pagoda.³ In the United Kingdom (UK), the Eatwell Plate⁴ has been used since 1995 and provides a visual representation of the types and proportions of major food groups needed for most healthy adults. This was updated in 2016, and is now called the Eatwell Guide⁵. The Eatwell Guide is split into five segments representing five food groups; 1) potatoes, bread, rice, pasta and other starchy carbohydrate foods (starchy CHO), 2) fruits and vegetables (F&V), 3) dairy and alternatives (dairy), 4) beans, pulses, fish eggs, meat and other proteins (protein), and 5) oils and spreads (oils) with the recommended proportions (by weight) being 38%, 40%, 8%, 12% and 1% respectively⁵ (Figure 1a). Two additional groups, which are placed outside the main pie diagram, are foods that are high in fat, salt and sugars (HFSS) and selected fluids (hydration). No recommended amount is given for the former, other than that foods in this category should be consumed infrequently and in small amounts, if at all. Six to eight glasses of fluid each day are recommended, with a limited contribution of 150ml per day from fruit juices and smoothies.

Dietary assessment tools are valuable in population monitoring and surveillance activities to measure how well people comply with dietary guidelines, and monitor trends over time.⁶ No dietary instrument exists to assess compliance with the Eatwell Guide at either a population or individual level. One of the most important issues in dietary monitoring is selecting an appropriate assessment measure, which depends on its purpose.⁷ As the Eatwell Guide calculations are based on the weight of food, weighed food diaries may be considered appropriate, however they can be costly, time consuming and have a high respondent burden, and can consequently result in a change in diet and a record that is unrepresentative of habitual diet,⁸ making them unsuitable for large scale population surveys.⁷ Estimated diaries reduce respondent burden. Twenty-four hour recalls require repeat measures to ensure the assessment

of habitual diet for an individual, although statistical methods can be applied to estimate usual dietary intakes using 24 hour recalls.⁹ Food frequency questionnaires (FFQs) have the advantage of measuring habitual diet and are a less labour intensive method of collecting dietary data at the population level,¹⁰ although portion weight is limited to fixed response options. Short dietary assessment instruments can give a broad measure of overall diet quality and monitor the population's progress towards national dietary recommendations.^{6, 11, 12} They are widely used in population health surveys¹³⁻¹⁵ reflecting their practicability in the context of a large representative national survey, particularly in situations when time is constrained and there is limited space for questions on diet. However, they only collect data on selected foods which may not be representative of all food groups.

The use of short dietary assessment tools and questionnaires to measure adherence to national dietary targets has been examined.^{6, 11, 16} In Australia, a food habits questionnaire and semi-quantitative FFQs have been used to measure adherence to food-based dietary guidelines.^{6, 11} In Scotland, a dietary targets monitor was previously evaluated for use in large scale surveys to assess population food intake in relation to key dietary targets based on the National Food and Health Policy.¹⁶ Currently, population adherence to the Scottish Dietary Targets is monitored through a short 24-item questionnaire.¹⁵ However, there is a lack of research examining the ability of dietary assessment tools to estimate the proportions of major food groups (i.e. 40% of intake from fruit and vegetables based on weight, as used in the Eatwell Guide) in comparison to portion size food group recommendations (e.g. 2 serves of fruit and 5 serves of vegetables). The present study aimed to compare the Eatwell Guide proportions calculated using an FFQ and a short dietary assessment tool to determine whether they can accurately estimate the Eatwell Guide proportions in adults living in Scotland compared with estimated food diaries.

METHODS

The study was of cross-sectional design carried out between July and December 2013. As the aim was to recruit a representative sample of Scottish adults, participants who had previously taken part in a nation-wide health survey (2010 Scottish Health Survey) and agreed to be contacted about further research, were invited to participate. The Scottish Health Survey recruited 8,473 adults who were randomly selected using postcode address files (response rate = 55%).¹⁷ For this study, the Scottish Health Survey team randomly selected 1,600 participants from the 2010 survey (800 men; 800 women). Eligible participants were aged 18-65 years old, living in Scotland and had complete data for sex, age, height, body weight, and Scottish Index of Multiple Deprivation Score (SIMD)¹⁸. Potential participants received a mailed envelope containing an invitation letter, a consent form, a general questionnaire and a freepost return envelope. This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects were approved by the [removed for blind peer review]. The reporting adheres to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement.

This study compared an FFQ, the Scottish Collaborative Group Food Frequency Questionnaire (SCG FFQ), with a short dietary assessment tool, the Scottish Health Survey Eating Habits Module (SHeS EHM). Participants completed the simpler dietary assessment measures first (SHeS EHM, then SCG FFQ and seven-day estimated food diaries (reference method)) to minimise the potential for responses to influence the subsequent measure. Participants completed estimated instead of weighed food diaries to reduce burden.

Dietary intake is assessed at a population level in Scotland through the SHeS EHM¹⁵; a component of the annual Scottish Health Survey. The EHM is a short 24-item interviewer-led questionnaire that assesses consumption of foods relevant to the Scottish Dietary Targets.¹⁵ The SHeS EHM collects fruit and vegetable intake data through a 24 hour recall using ‘everyday’ food portion terms (such as tablespoons, cereal bowls and slices) for the following food types; vegetables (fresh, frozen or canned); salads, pulses, vegetables in composite dishes; fruit (fresh,

frozen or canned), dried fruit, and fruit in composite dishes. The SHeS EHM also includes questions on the consumption of a variety of other food and drink items, to gather information on eating habits more generally. The SHeS EHM assesses frequency of consumption and, other than fruit and vegetable intake, was not designed to quantify amounts consumed.¹⁹ A trained researcher administered the SHeS EHM as a telephone interview, following the protocol used in the SHeS. Prior to the interview, participants were mailed response cards (outlining possible consumption amounts and frequencies) required for completing the SHeS EHM.

The SCG FFQ (version 6.6)²⁰ is a validated semi-quantitative instrument that has been developed to estimate and rank the dietary intake of a wide range of nutrients in large scale UK epidemiological studies.^{21, 22} The SCG FFQ covers 169 food items grouped into 21 categories (e.g. breads, and breakfast cereals). Possible responses for frequency of consumption range from “rarely”, through once per month, to seven day a week, and the number of serves (from 1 to 5+) consumed per day for the amount usually consumed. Standard household measures (e.g. 1 tablespoon, 1 teaspoon) or items (e.g. 1 small cake, 1 medium slice) are listed as portion size responses. Standard portion sizes for foods and beverages were assigned²³ per serve. The SCG FFQ was used to describe each participant’s habitual diet over the previous two to three months.²⁰ Participants received the paper-based SCG FFQ via mail and returned the FFQ within one week. Participants received a reminder letter if they failed to return the FFQ. Participants with >10 missing responses were contacted by telephone and asked to clarify responses and provide missing information.

Participants also completed a seven-day estimated food diary, starting on different days of the week and completed over consecutive days. Participants recorded all food and beverages consumed in a paper-based diary, which included standard food portion size photographs²⁴ to help them describe the quantities of foods and drinks consumed. Participants could also report weights from packaged food, record brand names of commercial products, and identify if ‘low-fat’, ‘low sugar’, ‘low calorie’, or ‘diet’ products were used, to aid identification of the correct

food item (or closest substitute) in the food composition tables. Participants received a reminder letter if they failed to return their completed diary and were contacted by telephone to clarify responses and provide missing information if necessary. Food diary data were analysed using Wisp 4.0 (Tinuveil Software 2013) using the UK food composition tables.²⁵

Food and drinks were categorised to the Eatwell Guide food groups (based on weight in grams) for the SHeS EHM, SCG FFQ and food diary. Because the SHeS EHM does not assess portion size, each food item was assumed to represent the consumption of one average serving of food, as with other non-quantitative surveys.^{6, 11, 16} Average serving sizes were estimated from UK reference food portion sizes.²³

For the food diary, foods were categorised according to their weight after preparation, taking into account cooking weight changes and food preparation losses where necessary. If the raw weight of foods (i.e. from recipe components) were recorded, these food weights were converted to 'as eaten' weights by adjusting for weight changes using the edible conversion factor in the food composition tables and cooking weight changes.²⁵ For composite dishes that contained food items from more than one food group, such as lasagne, the dish was disaggregated and the appropriate proportion was assigned to the applicable Eatwell food group²⁶ using representative recipes from food composition tables²⁵ (n=39), internet sources (n=67), or from the list of ingredients (n=99).

As recommended, the weights of all liquids (i.e. milk and fruit juices) in the Eatwell Guide were halved to adjust for their high water content (and therefore weight) having a large effect on the Eatwell Guide proportions.^{27, 28} The water content of soups was removed from the calculations. Similarly, the protocol used for soft drinks in the development of the Eatwell Guide²⁹ was also applied to the food diary, SHeS EHM and SCG FFQ, with calculations performed based on sugar content only and assigned to the HFSS food group. Sugar content in soft drinks was obtained from food composition tables²⁵ or product labels. Alcoholic beverages and

miscellaneous foods that are not included in the Eatwell Guide (such as sauces, pickles, tea and coffee) were assigned to a miscellaneous food group for completeness but were not analysed. The process to calculate each participant's Eatwell Guide proportions involved four steps outlined in Appendix 1. Basal Metabolic Rate (BMR) was estimated using the equations of Schofield³⁰, and the ratio of reported energy intakes from the SCG FFQ and estimated food diaries to BMR calculated to assess the plausibility of the dietary intakes.³¹

Data were analysed using SPSS Version 22 (SPSS/IBM Corp, Armonk, New York, NY).

Dietary data from the study were linked with demographic data collected during the 2010 Scottish Health Survey, which included both continuous (e.g. age) and categorical variables (e.g. sex, SIMD, area of residence). Anthropometric data (height and weight) were objectively measured during a home visit as part of the original data collection. Height was measured in cm to the nearest 0.02cm using portable stadiometers (unspecified make and model). Weight was measured in kg to the nearest 100g (Tanita THD-305 or Seca 870 scales). Participants who reported SCG FFQ energy intakes at the highest and lowest 2.5% of the sample were excluded, in line with the current University of Aberdeen internal SCG FFQ standard operating procedure (SCG-FFQ SOP 5: Analysing and interpreting data). The absolute amounts (g/day) of the Eatwell Guide categories by the three assessment methods were compared using Friedman tests as the data were skewed and the concurrent assessment measures were not independent. Wilcoxon signed rank tests were subsequently performed to test for differences between pairs of assessment measures.

The proportions of the Eatwell Guide categories calculated from the food diary, the SHeS EHM and SCG FFQ were compared using the Aitchison method, which computes the distance between two sets of composition data.³² This method measures the distance as multi-axis vectors where there are, in the case of the Eatwell Guide, five axes (one for each of the Eatwell Guide food groups that make up the pie diagram), and calculates the sum of the distances between the two methods. The Aitchison method compares the distance between compositional

data collected using a reference method (x; e.g. food diary) and different test methods (y; SCG FFQ or SHeS EHM). The minimum Aitchison distance value is zero (for perfect agreement between the two methods), and the maximum would be 16.3, as used in these analysis. A Wilcoxon Signed-Rank Test determined whether the SCG FFQ or SHeS EHM had a lower set of Aitchison distance values. Significance levels were set at $p < 0.05$. Bland-Altman analyses assessed mean difference and 95% limits of agreement between the SCG FFQ or SHeS EHM and the food diary for each of the five food groups.³³ Comparisons between the SHeS EHM and the food diary were not made for the oils and spreads food group because the SHeS EHM contains no questions on these.

RESULTS

One hundred and fifty participants agreed to participate (response rate of 10%; Appendix 2). Forty-nine participants dropped out prior to completing all three dietary assessment measures, leaving 101 participants (67%) with complete data. According to the SCG FFQ protocol, five participants reporting energy intakes at the highest and lowest 2.5% of the sample were removed from the analysis, with 96 participants in the final sample analysis. The mean (SD) ratio of reported energy intake to BMR was 1.62 (0.43) and 1.13 (0.27) for the SCG FFQ and estimated food diary methods respectively, with 10 (11%) and 51 (53%) participants being below the method specific cut-off for plausible reports ($1.14 \times \text{BMR}$ and $1.10 \times \text{BMR}$ respectively). The sample had a mean (SD) age of 51.4 (11.1) years, and BMI of 27.1 (4.9) kg/m^2 (Appendix 3). The sex proportion (57% women) and BMI (27.4 kg/m^2) of the 2010 SHeS sample³⁴ was similar to the sex distribution and BMI of participants in the current study. However, more participants in the 2010 SHeS sample lived in an urban location (72%) and there was a more even distribution of participants across the five SIMD quintiles than in the current study (median: Quintile 3).³⁵

Absolute amounts (g/day) of the Eatwell Guide foods as measured by the three methods are reported in table 1. The proportions of food consumed from each of the five Eatwell Guide categories (according to the food diary) are reported in Figure 1b. In comparison to the Eatwell Guide recommendations (Figure 1a), the participants consumed too few starchy CHO foods (26% vs. 38% recommended), and less than the recommended amount of F&V (34% vs. 40% recommended). The contribution of dairy foods and protein foods were higher than recommended (21% and 18% vs. 8% and 12% recommended respectively).

The SCG FFQ scored a lower median Aitchison distance (1.47) than the SHeS EHM (1.99), meaning that the SCG FFQ was closer to the food diary in estimating the Eatwell Guide proportions in comparison to the SHeS EHM (Table 2) (Wilcoxon Signed-Rank Test: $p < 0.001$). A visual representation of the dietary intake of the participants as assessed through the SHeS EHM and SCG FFQ is shown in Figure 1 (c and d, respectively). Breaking the analysis down by Eatwell Guide food group categories, the SCG FFQ and SHeS EHM were similar in their ability to estimate four of the five food groups with the oil and spreads being notably different as this food group was not fully captured by the SHeS EHM or the SCG FFQ, although this food group contributes relatively little to the overall weight of food (g) consumed. Bland-Altman Plots (Figure 2 and Table 3) to assess relative agreement between the SCG FFQ and food diary showed good agreement for the F&V, starchy CHO, dairy and protein food groups, but evidence of decreasing agreement with increasing contribution of oils and spreads to the diet. The SHeS EHM showed poorer agreement with decreasing agreement with higher intakes of F&V and protein foods. The SHeS EHM appeared to show increasing underestimation of the dairy, and oils and spreads food groups with higher intakes. The latter being because the SHeS EHM did not estimate intakes of oil and spreads at all.

DISCUSSION

The study found that the SCG FFQ was closer to the food diary in estimating the Eatwell Guide proportions, but when broken down by food group categories, the SCG FFQ and SHeS EHM were similar in their ability to estimate four of the five food groups (starchy CHO, F&V, dairy and protein) but not for oils and spreads. There was good relative agreement between the SCG FFQ and food diary for the same four food groups, but evidence of decreasing agreement with increasing contribution of oils and spreads to the diet. The SHeS EHM showed poorer agreement with decreasing agreement with higher intakes of F&V and protein foods. The SHeS EHM appeared to show increasing underestimation of the dairy, and oils and spreads food groups with higher intakes (as the SHeS EHM did not estimate oil and spreads).

Although a new tool to assess adherence to the Eatwell Guide could have been constructed as other studies have done⁶, choosing existing questionnaires enabled us to determine the value of two functioning dietary assessment instruments that have been used to measure the dietary intake of the Scottish population. The SHeS EHM and SCG FFQ were chosen as they are used to measure dietary intake at a population level and they have been adapted to reflect the eating habits of the Scottish population.^{15, 20, 34}

The study also identified discrepancies in the SHeS EHM in assessing the Eatwell Guide proportions (i.e. substantial under or overestimation). The difference between the food diary and SHeS EHM was greatest for the dairy category. Bland-Altman plots indicated increasing bias with higher intakes of dairy foods; reflecting the limited dairy-related questions in the SHeS EHM. While the SHeS EHM asks participants to identify the type of milk usually consumed and the frequency of consumption of cheese (not including cottage cheese and other reduced fat cheese) there are no questions assessing the frequency of consumption for milk, yoghurt, or reduced fat cheese, meaning that any intake of these foods could not be included in the analysis. This contributed to an inaccurate dairy proportion calculation of 6% in the SHeS EHM, in comparison to the reference proportion by the food diary of 21%. The SHeS EHM had no questions that related to the frequency of consumption of oils and spreads, and the amount

(g/day), and therefore contribution of this food group to total intake, was zero for all participants. Consumption of spreads can be only partially estimated from the types of spreads used and the amounts usually used on bread and toast in the SCG FFQ. Estimation of the oils and spreads food group of the Eatwell Guide by the SCG FFQ could be improved with one additional question on the amount and frequency of consumption of oils used for cooking and in dressings, and one on the amount and frequency of spreads used in cooking and baking. Absolute intakes of the remaining Eatwell Guide's main food groups, and the discretionary HFSS group were significantly higher when estimated by the SCG FFQ than the food diary, but the proportions of the main food groups were similar. Generally, FFQs tend to overestimate intakes relative to food diary methods.

The underestimation of the dairy proportion by the SHeS EHM, influences the accuracy of proportions from the other food groups since the proportion estimates for each food category rely on the sum of the weight of all foods as the denominator. Despite this limitation, the data were analysed based on proportion estimates and not absolute frequency or quantity because the purpose of this study was to examine the ability of the SHeS EHM and SCG FFQ to measure population adherence to the Eatwell Guide recommendations which are based on proportions of the major food groups. The large discrepancy in fruit and vegetable proportions between the SHeS EHM and the food diary may be because the high fruit and vegetable intake assessed through the SHeS EHM is unrepresentative of habitual intakes due to the small sample size (n=96) combined with the shorter reporting period of a single 24 hour recall. The Eatwell Guide fruit and vegetable food group was estimated at 28.8% in the 2008 – 2011 National Diet and Nutrition Survey, which uses 4-d food diaries to collect dietary data

The study also identified other methodological limitations inherent in the application of the Eatwell Guide. Since the weight of food is used to calculate the food group proportion, it assumes that foods within the same food group have the same nutritional quality regardless of weight. For example, 100g of unprocessed meat (e.g. chicken breast, beef steak) and 100g of

processed meat products (e.g. chicken nuggets, sausages) are considered an equivalent meat product, despite having distinct differences in fat, saturated fat, sodium, and actual meat content.²⁵ Other international plate-based food models^{1, 2} provide more guidance with regards to portion size (e.g. serving size for every food group, recommended servings/day, and approximate energy from one food serving) which is limited in the Eatwell Guide.³⁶ Without guidance on portion sizes and recommended servings per day, a person could overconsume food and in theory still meet the Eatwell Guide recommendations, providing they overconsumed proportionately in all food groups. Another challenge in analysing dietary data by food group is that many meals are in the form of dishes with ingredients from more than one food category (combination/ composite foods).^{26, 37} To accurately monitor dietary intake participants need to identify the primary ingredients and quantities in the composite dishes they consume, and identify how these ingredients fit within the proportions recommended by the Eatwell Guide. Using existing dietary assessment tools (such as those used in the current study) moves this requirement from the participant to the researcher thereby reducing participant burden and allowing consistency in the breakdown of composite dishes into the Eatwell Guide food group proportions. The SCG FFQ can also provide estimated intakes (g per day) of macro and micronutrients, whereas the advantages of the SHeS EHM include its lower participant burden and ease of data entry. Thus, the choice of dietary assessment method to estimate Eatwell Guide proportions may be influenced by the trade-off between estimating nutrient intakes and participant workload.

There are limitations in the study. While the food diary (reference method) cannot measure ‘true’ dietary intake, using measurement instruments that rely on different factors (e.g. memory, fixed list of foods, perception of portion sizes), avoid introducing similar biases, and have different associated measurement errors, may prevent an overestimation of agreement of dietary intake in validation studies.⁷ Self-reporting dietary intakes usually leads to a change in the amounts and types of foods consumed during the reporting period, for ease of reporting and

because of social desirability, producing estimates of energy intake that tend towards being lower than habitual intakes⁸ (as evident through the food diary). Under-reporting of foods when recording dietary intake is common, if not universal, across all methods of self-reported dietary assessment⁸, and there is no satisfactory method of adjusting for this without introducing additional bias. While participants spanned across all SIMD quintiles, the most deprived SIMD quintiles were under-represented. The sample is likely to be primarily of highly motivated people, whose dietary intake and knowledge and interest in their diet may differ from the general population. The study had a low response rate of 10% that was probably a consequence of the three-year gap between the original SHeS and current Eatwell Guide Study. Although the study sample was representative of the 2010 Scottish Health Survey sample based on sex and BMI,¹⁷ more participants in the Scottish Health Survey sample lived in an urban location than in the Eatwell Guide study.

The Eatwell Guide is the UK's policy tool for collating and disseminating the government's healthy eating recommendations. Currently, no dietary assessment instrument exists to assess compliance with the Eatwell Guide at either a population or individual level, and it is not possible to measure how well the UK population complies with the Eatwell Guide, or monitor trends over time. The findings of this study suggest that the SCG FFQ in its current state could fill the gap and could be improved with small changes. However, the FFQ takes 20-30 minutes for the participant to complete, which may be considered too time-consuming for monitoring dietary intake in a general health survey in which other health indicators, such as mental health and wellbeing, physical activity, dental health, smoking and long-term health conditions as well as physical measurements are made.¹⁵ The SHeS EHM is less suitable, however, it is long running (1995 to present day), and included in the current 'rolling programme' which started in 2008. Modifying the existing SHeS EHM to provide a closer estimate of the Eatwell Guide proportions may be favourable. Additional questions could be incorporated into the SHeS EHM that estimate quantities of i) milk, ii) yoghurt iii), reduced fat cheese iv), oils and v) spreads

consumed each day, to achieve this. A modified SHeS EHM would need retesting for accuracy of estimating the Eatwell Guide proportions to determine whether other adjustments are needed.

This study assessed whether a FFQ and short dietary assessment tool can be used to accurately estimate the Eatwell Guide proportions of diets of adults living in Scotland. The SCG FFQ provided a slightly closer estimate of the Eatwell Guide proportions and better agreement, relative to the food diary, than did the SHeS EHM. However, for the purpose of including in the Scottish Health Survey and if time is constrained, it may be preferable to modify the existing SHeS EHM, as suggested above, to provide a closer estimate of the Eatwell Guide proportions. Appropriate retesting for accuracy would be needed.

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Conflict of interest

The authors have no conflicts of interest to declare.

Authorship

SW, LCAC and GM were responsible for the design of the study. JLH, SW, LCAC and GM formulated the research question. SW and LCAC carried out the study. JLH, LG, SW and HC completed the data entry. JLH, LG and SW conducted the statistical analysis. JLH completed the literature review and drafted the initial paper. All authors were responsible for drafting and revising the manuscript and have approved the final version.

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Table 1. Number of foods contributing to each Eatwell Guide food group as measured by the seven-day food diary estimate (reference method), SHeS EHM and SCG FFQ (n=96), and median (interquartile range) daily intakes (g/day).

	Assessment method	Fruit & vegetables	Starchy CHO	Oil & spreads	Dairy	Protein	HFSS	Hydration
Number of foods	Food diary	24	25	15	26	34	46	12
	SHeS EHM ¹	15	5	0	2	21	12	6
	SCG FFQ ¹	41	38	3	20	43	52	13
Daily intake	Food diary	277 ^{AB} (180 - 363)	184 ^{AB} (154 - 244)	4.7 ^A (1.3 - 10.1)	156 ^{AB} (101 - 215)	130 ^{AD} (95 - 184)	138 ^{AD} (101 - 192)	654 ^B (461 - 905)
	SHeS EHM	490 ^B (297 - 684)	244 ^{BC} (169 - 291)	N/A	53 ^{BC} (41 - 69)	159 ^{CD} (111 - 219)	160 ^D (87 - 274)	257 ^{BC} (203 - 413)
	SCG FFQ	465 ^A (309 - 670)	319 ^{AC} (237 - 443)	0 ^A (0 - 6.0)	223 ^{AC} (161 - 323)	201 ^{AC} (149 - 289)	191 ^A (125 - 262)	704 ^C (522 - 904)
	Wilcoxon Signed-Rank test (p-value)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Abbreviations: Scottish Health Survey Eating Habits Module (SHeS EHM), Scottish Collaborative Group Food Frequency Questionnaire (SCG FFQ).

Foods high in fat, salt and sugar (HFSS). Values with the same letter in each column were significantly different, Wilcoxon Signed-Rank test.

Statistically significant differences in the values of daily intake of each food group, as measured by the three assessment methods are indicated by the same superscript letter in each column; values in each column (i.e. food group by the three assessment methods) with the same letter are statistically different; A, B, C $p < 0.001$. D $p < 0.005$.

1 **Table 2.** Median (inter quartile range) Aitchison distance between the seven-day food diary estimate (reference) and SHeS EHM and SCG FFQ (n=96).

Assessment method	Aitchison distance					
	Fruit & vegetables	Starchy CHO	Oil & spreads	Dairy	Protein	Total
SHeS EHM	0.115 (-0.508 - 0.413)	0.455 (-0.025 - 0.798)	N/A	1.73 (1.21 - 2.13)	0.425 (-0.060 - 0.760)	1.99 (1.690 - 2.49)
SCG FFQ	0.190 (-0.370 - 0.710)	0.320 (-0.268 - 0.660)	0.330 (-0.035 - 1.41)	0.325 (-0.255 - 0.825)	0.265 (-0.125 - 0.783)	1.47 (0.983 - 1.880)

2 Abbreviations: Scottish Health Survey Eating Habits Module (SHeS EHM), Scottish Collaborative Group Food Frequency Questionnaire (SCG FFQ).

3 The Oil & spreads component of the Aitchison distance could not be calculated as all values were zero for the SHeS EHM method.

4 Note: Lower Aitchison distance indicates better agreement with the reference.

5

1 **Table 3.** Mean difference (bias) and 95% limits of agreement for the difference in food group proportion between the SCG FFQ-food diary and SHeS-
2 food diary.

Eatwell Guide food group	SHeS EHM			SCG FFQ		
	Mean bias (%)	Upper limit of agreement (%)	Lower limit of agreement (%)	Mean Bias (%)	Upper limit of agreement (%)	Lower limit of agreement (%)
Fruits & vegetables	11.60	43.60	-21.04	2.56	23.31	-18.61
Starchy CHO	0.03	22.78	-23.18	0.53	17.26	-16.55
Oil and spreads	N/A	N/A	N/A	-0.58	1.51	-2.71
Dairy	-14.59	4.97	-34.56	-1.28	17.32	-20.26
Protein	0.75	22.85	-21.80	-1.23	12.43	-15.16

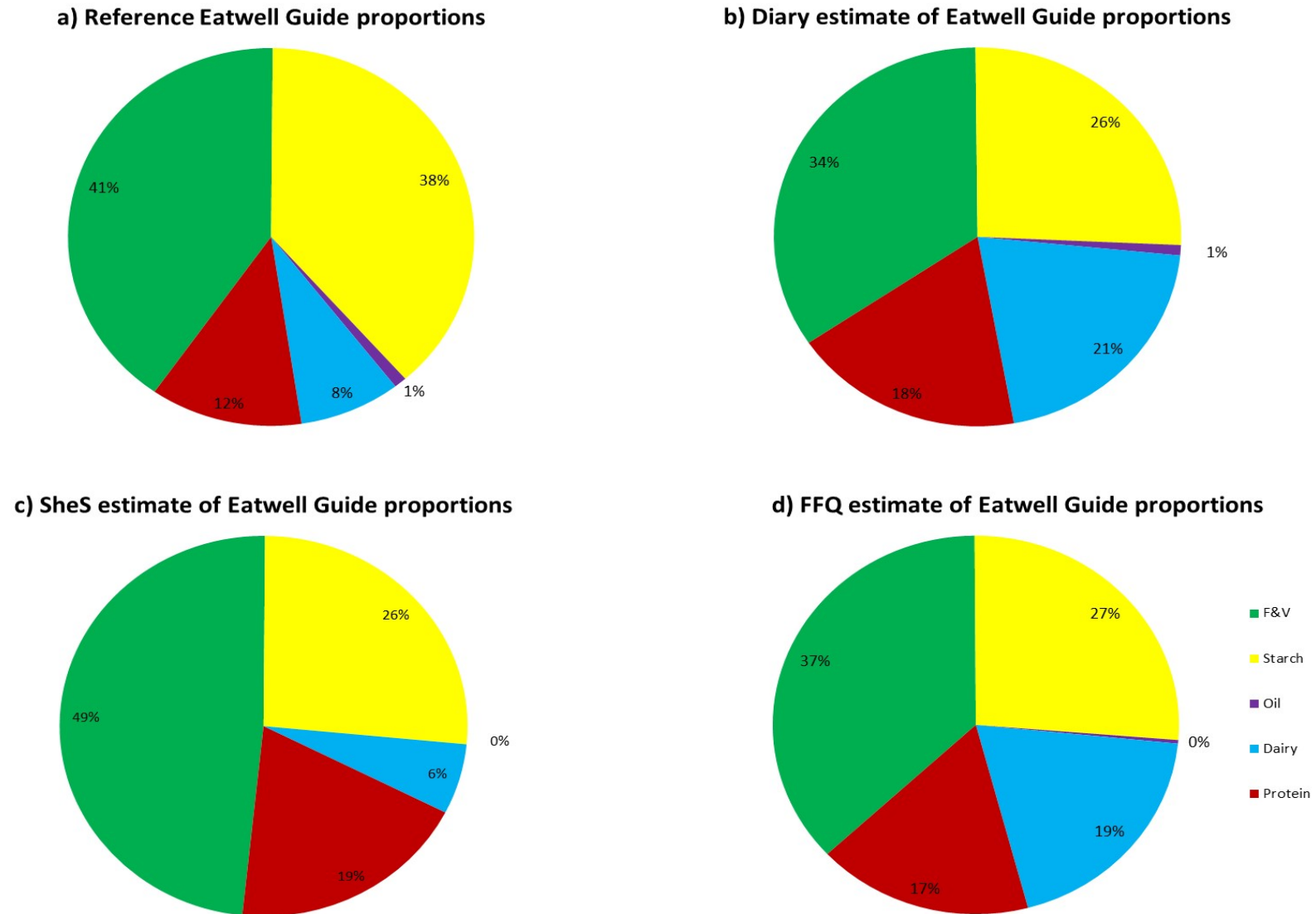
3
4 Mean bias is the mean difference between the assessment method and the reference method. Upper limit of agreement is the mean bias + 1.96 * SD, and
5 the lower limit of agreement is the mean bias - 1.96 * SD. Values for the difference between the SheS EHM and the food diary for the food group oils
6 and spreads are not applicable (N/A) (see manuscript text).

1 **FIGURE LEGENDS**

2 **Figure 1.** The Eatwell Guide proportion recommendations (a) ⁵ and the mean dietary intake
3 proportions by weight as calculated from a seven-day food diary (b), SHeS EHM (c) and the
4 SCG FFQ (d).

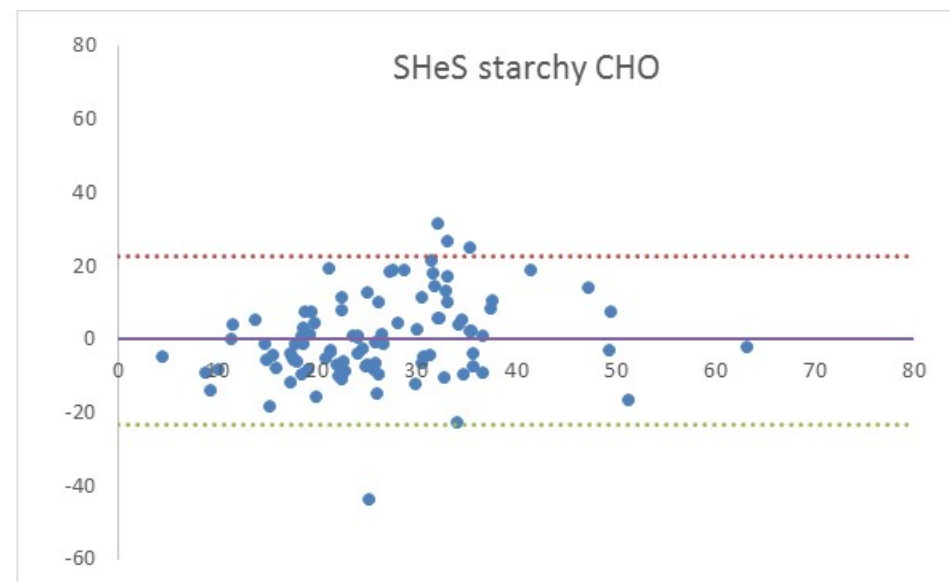
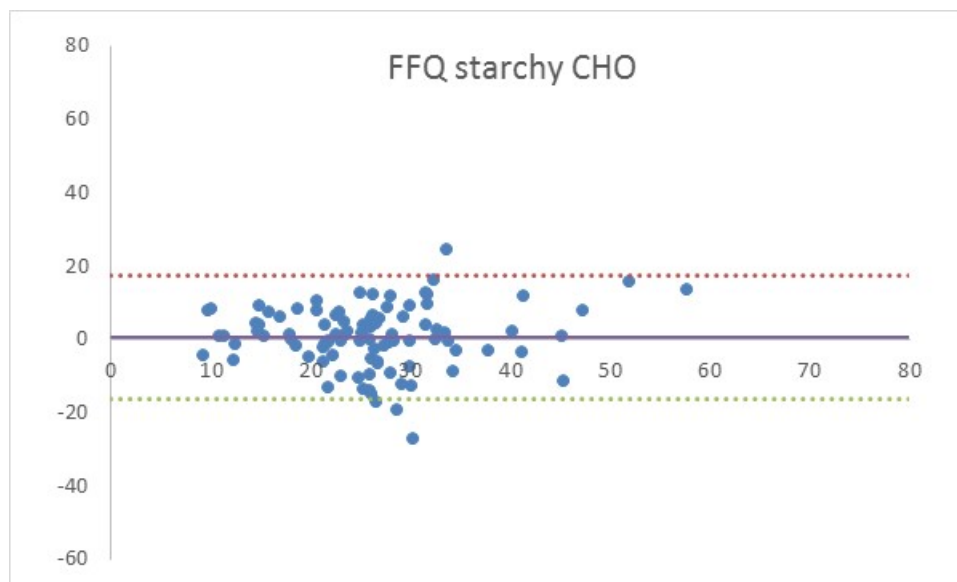
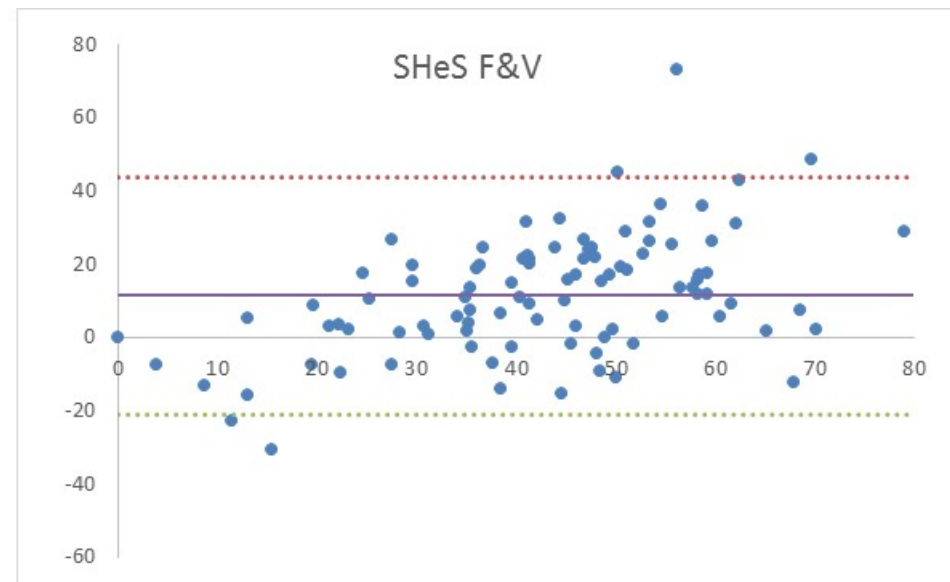
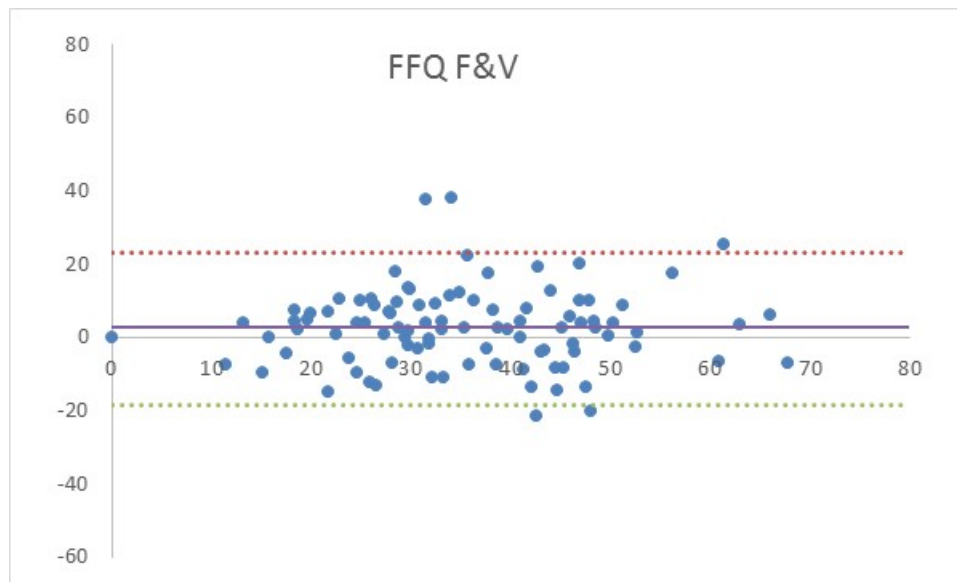
5 **Figure 2.** Bland-Altman plots to assess the relative agreement for each of the five food groups
6 between the SCG FFQ and SHeS and an estimated food diary in healthy adults aged 18-65 years
7 living in Scotland.

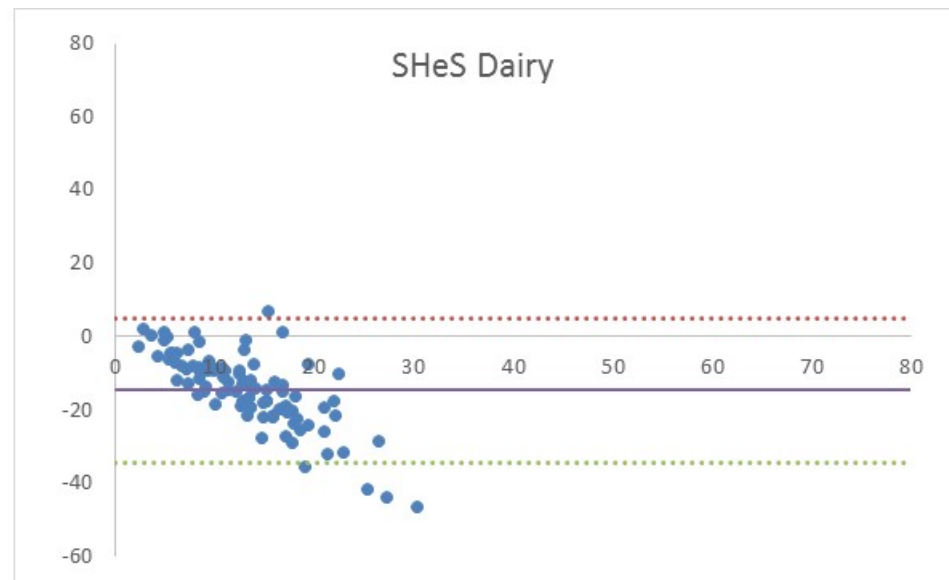
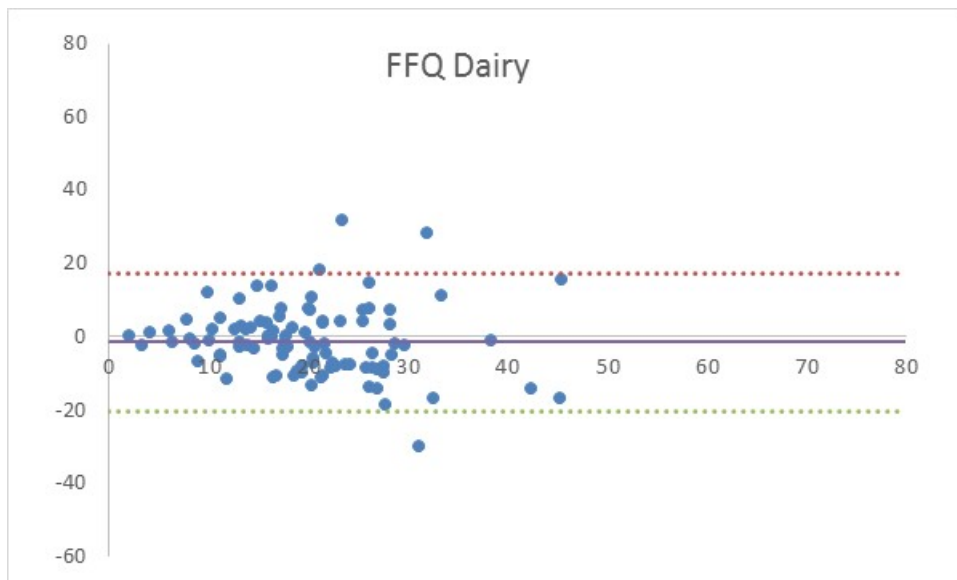
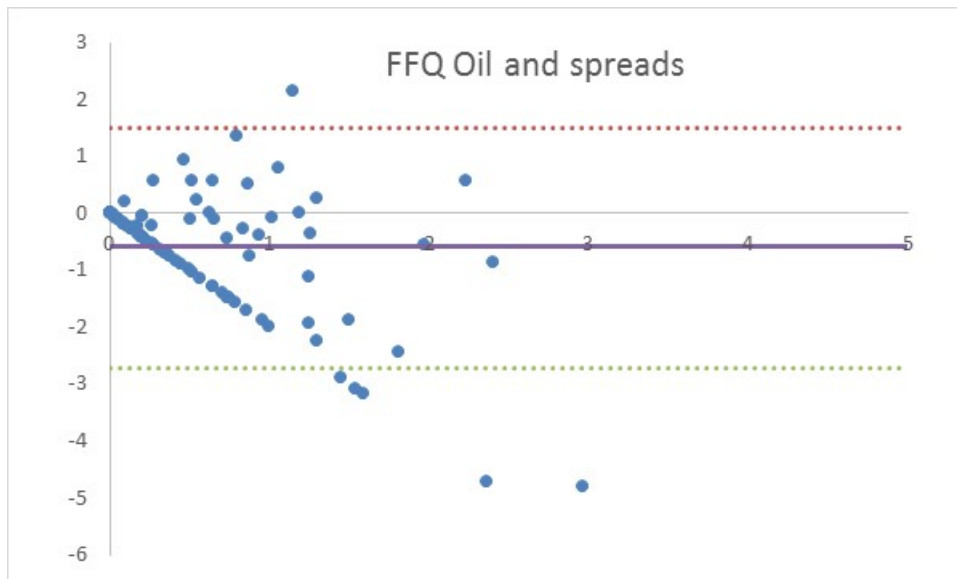
Figure 1.

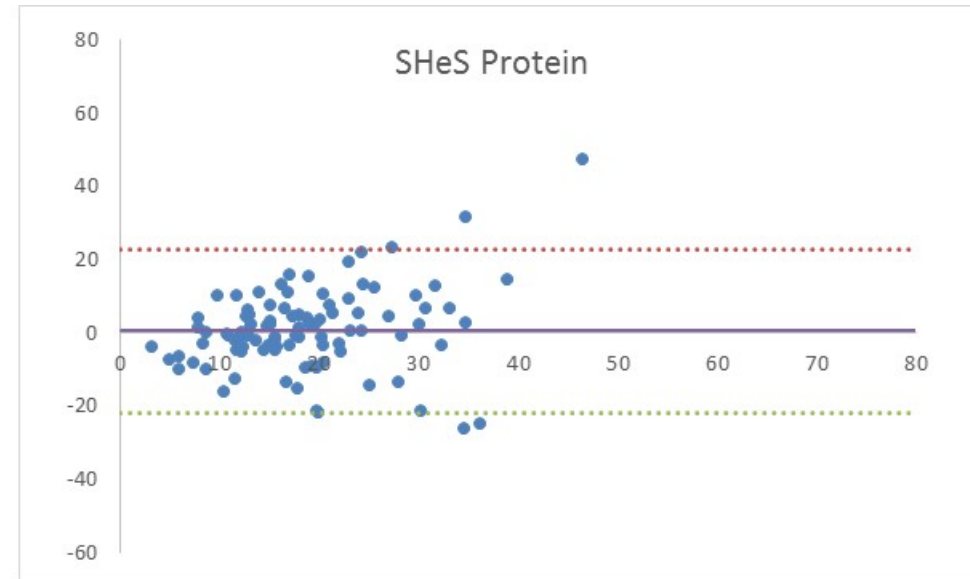
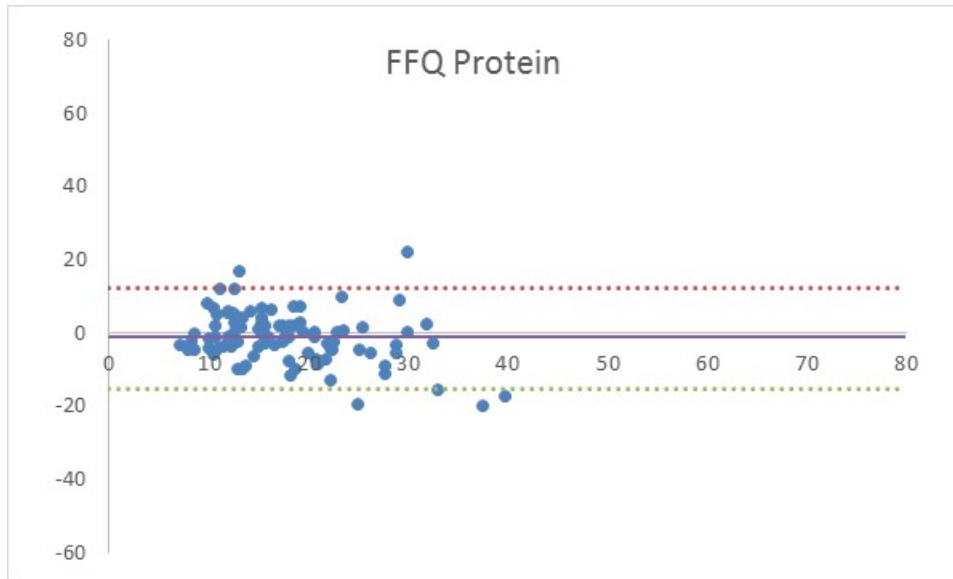


Abbreviations: Fruits and vegetables (F&V), Scottish Health Survey Eating Habits Module (SHeS EHM), Scottish Collaborative Group Food Frequency Questionnaire (SCG FFQ).

Figure 2.







Abbreviations: Scottish Health Survey Eating Habits Module (SHeS), Scottish Collaborative Group Food Frequency Questionnaire (FFQ), Starch: bread, rice, potatoes, pasta and other starchy foods, F&V: fruit and vegetables, Dairy: milk and dairy foods, HP: meat, fish, eggs, beans and other non-dairy sources of protein, and HFHS: foods and drinks high in fat and sugar.

Note: The difference in food group proportion between the SCG FFQ-food diary and SHeS-food diary is plotted *versus* the mean proportion from the two respective methods, where — represents the mean difference (bias) and ----- represents the 95% limits of agreement. In the Bland Altman plots, the Y axis shows the difference between the two paired food group proportion measurements (e.g. SCG FFQ and estimated food diary (reference)) and the X axis represents the average of these measures ((SCG FFQ + estimated food diary (reference)) / 2). The plot for the difference between the SHeS and the food diary for the food group oils and spreads is not shown (see text).

Appendix 1. The steps used to calculate each participant's Eatwell Guide proportions according to their dietary intake.

1) Allocating each food and drink to the appropriate Eatwell Guide food group (*e.g. fruit juice was allocated to 'fruit and vegetables' and to 'hydration'; butter to HFSS, low-fat spread to 'Oil and spreads', low-fat milk to 'dairy' and 'hydration, and full-fat milk to 'dairy' only).*

2) Calculating the weight of each food and drink consumed (*e.g. 200g of fruit juice*), taking into consideration any food conversion factors for liquids or sugar in soft drinks (*e.g. 0.5 conversion factor for liquids, therefore the adjusted weight of the fruit juice is 100g*) and any preparation and cooking weight changes (*e.g. 1.0 factor as there are no preparation or cooking changes for fruit juice, therefore the adjusted weight of the fruit juice is 100g*).

3) Applying contribution caps to the 'fruits and vegetables' group: 150ml per day for the fruit juice or smoothie contribution, and 80g per day for the beans and pulses contribution.

4) Summing the adjusted weight of each food and drink within their respective Eatwell Guide food groups (*e.g. Fruit and vegetable: 100g fruit juice + 150g apple + 60g carrots + 90g broccoli = 400g*)

5) Dividing the total adjusted weight of each of the five Eatwell Guide food groups that make up the pie chart by the total weight of food consumed from the five food groups, and multiplying by 100 to express the proportion as a percentage. (*e.g. 400g of fruit and vegetables / 1300g total weight of food = 30.8%*)

Appendix 2. Reasons for non-participation in the study at each stage.

Of the 1,600 Scottish Health Survey participants invited to participate in the study, 19 were uncontactable due to incomplete address details, three had died, and 124 forms were returned as participants were no longer located at the address. Fifteen participants returned forms indicating they did not want to participate and no response was received from 1289 participants. One hundred and fifty participants agreed to participate (response rate of 10%). Forty-nine participants dropped out prior to completing all three dietary assessment measures, leaving 101 participants (67%) with complete data. According to the SCG FFQ protocol, five participants reporting energy intakes at the highest and lowest 2.5% of the sample were removed from the analysis, with 96 participants in the final sample analysis.

Appendix 3. Demographic Characteristics of the Participants Who Completed the Eatwell Guide Study (n=96).

Demographic characteristics		Mean (SD)	
Age (years)		51.4 (11.1)	
BMI (kg/m ²) ^(a)		27.1 (4.9)	
		Number (n)	Percentage (%)
Sex	Male	40	42
	Female	56	58
Residence	Large urban areas	29	30
	Other urban areas	27	28
	Accessible small towns	6	6
	Remote small towns	10	10
	Accessible rural areas	7	7
	Remote rural areas	17	18
SIMD	Quintile 1 (<i>most deprived</i>)	10	10
	Quintile 2	11	12
	Quintile 3	28	29
	Quintile 4	25	26
	Quintile 5 (<i>least deprived</i>)	22	23

Abbreviations: Body Mass Index (BMI), Scottish Index of Multiple Deprivation (SIMD), Standard Deviation (SD).

^(a) BMI was calculated based on weight and height measurements taken at the time of the 2010 Scottish Health Survey.